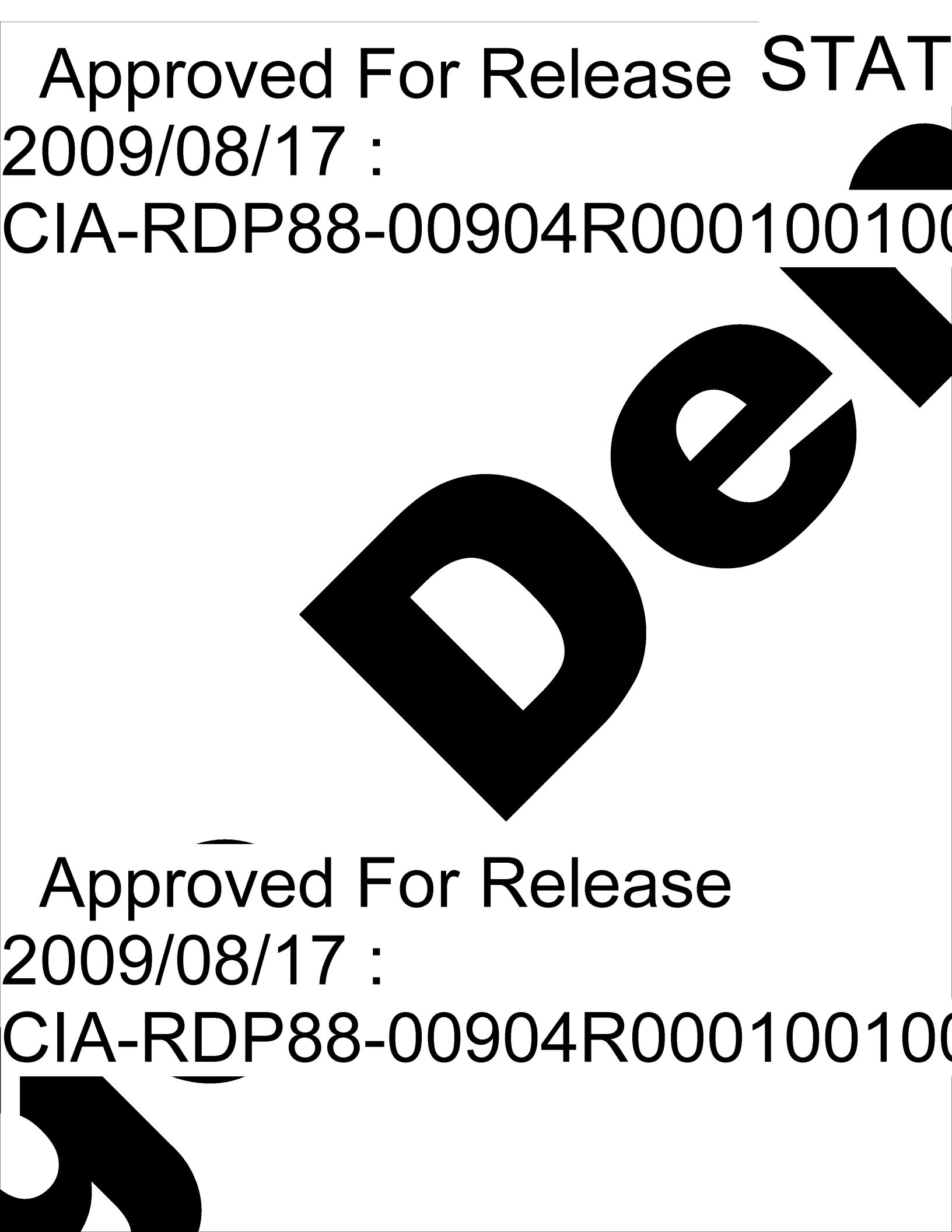

Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/P/325
USSR
May 1964
Original: RUSSIAN

Confidential until official release during Conference

THE EXPERIENCE OF OPERATION AND USE OF THE RESEARCH WWR-M REACTOR WITH MAXIMUM NEUTRON FLUX 3.10^{14} $\frac{n}{cm^2.sec}$.

D.M. Kaminker, K.A.Konoplev.

The research WWR-M reactor has been put into operation in the A.P.Ioffe Physical and Technical Institute of Academy of Science of the USSR since December 1959.

The reactor uses enriched uranium, light water as a moderator and beryllium as a side reflector. It operates at a rated heat power of about 10 MW. (1,3,11).

The reactor was designed as research one and is employed to carry out investigations in nuclear physics, solid-state physics, radiobiology and radiochemistry. Main investigations are carried out using horizontal channels of the reactor.

All these investigations are mainly being carried out by Physical and Technical Institute (2) with the aim to study the structure of nuclei and isotope characteristics, the mechanism of fission process and primary actions of radiation influence and also the utilization of neutron beams as a method of investigation of the structure and properties of different substances.

I. DESIGN AND OPERATION OF THE REACTOR.

The first operating reactor loading (Fig.1) had a stretched form to separate the water cavity from the control rods and to keep their worth. The flux of thermal neutrons in the cavity was 3.6 times greater than the mean flux in the core. The loading of U^{235} was amounted to 3120 g.

The water cavity is formed by means of the replacement of 12 fuel elements by a special channel for the irradiation of samples. The formation of the water cavity to create an experimental channel with maximum thermal neutron flux is one of the ways of using the great mobility of the core. The core is formed of fuel elements (Fig.2-3) and beryllium elements within the loop of the beryllium reflector. Various operations of the core give the possibility to change fluxes in experimental channels from 0.4 to 1.5 of the mean thermal neutron flux in the core (4,5).

At 10-MW reactor power the thermal neutron flux in the water cavity is $3.10^{14} n/cm^2.sec$ and it is $(1.4 \div 0.4).10^{14} n/cm^2.sec$ in other experimental channels. Flux measurements were made by the activation of gold foils 0.1mm thick for relative measurements, and 100 ÷ 200 Mg/cm^2 thick for absolute measurements by method of β-γ- coincidence. By May 1964 the heat output of the reactor has reached 2000Mw-days. After 200-300 Mw-days are obtained, new fuel elements are loaded into the reactor with some replacement of the burnt out elements.

After the additional charge the criticality of a cold depoisoned reactor is achieved only after the extraction of all safety rods and of at least a half of one of shim rods. Such a system provides sufficient reactivity for operation during the whole period between the loadings at the power of 5MW and higher (Fig.5). The maximum weight of 6 control and shim rods is 9.3%, the reactivity for poisoning at the power of 5 MW is 2.5%. For burning out [illegible] days is spent. All values of the reactivity are calculated taking into account the [illegible] neutrons worth for WWR-M reactor (6). Though the weight of the control rods has turned out to be less than expected according to the preliminary calculations (3), it hasn't caused any difficulties in operation.

Water treatment and water-purifying systems in the primary loop of WWR-M reactor were not good enough and we had to replace and modify them.

A system of ionexchanging column (7) was made to supply the reactor with make up water instead of electric-distiller units. This system provides a good quality of water. A good quality of water is also maintained by an ionexchanging filter which is placed on the by-pass of the primary loop system (Table 2).

During operation the quality of water changes but little, thus allowing of checking constantly only one rather characteristic parameter. Now-used control system is given in Table 3. The corrosion resistance of the loop elements made of stainless steel is high enough, partly due to chemical and mechanical treatment of the primary loop elements before the reactor start-up. The stainless steel corrosion products influence little the quality of water (9). Aluminium corrosion influences greatly the quality of water. The working conditions of the coolant are represented in Table 1. The existence of aluminium hydroxide in the water of the primary loop results in the sorption of the hydrated oxide on rough parts of the beryllium surface. Moreover, in stagnant water the holes of the beryllium parts can be completely overlapped. To prevent such a sorption the water of the primary loop is periodically pumped through even when the reactor is out of operation. Aluminium corrosion reaches 2 grams per day and results in the formation of insoluble particles the size of which varies from 5 to 30 microns. These particles consist of hydrated-aluminium-oxide (Fig.4). With the concentration of such particles 2 ÷ 3mg/l, water grows turbid and the visibility of the core reduces. With the concentration as high as 10 mg/l the core immersed by 3.5m into the water is quite invisible and fuel recharging cannot be executed. The elements of corrosion as suspensions were observed in other reactors such as the Canadian NRU reactor in which they were in the form of Gibbsite $2Al_2O_3 3D_2O$ (8).

To clear the water in the primary loop of the WWR-M reactor an electrophoretic filter was constructed (2). In such a filter the turbid water is flowing between two electrodes. Suspended charged particles are precipitated on the electrodes and then a pure water is flowing out of the filter (Fig.6,7). The purification coefficient of the filter is $\xi = 0.9 \div 1.0$.

$$\xi = \frac{C - C'}{C}$$

where C and C' are concentrations of suspensions at the inlet and outlet of the filter. The effective flow rate through the filter ξQ (where Q is a total flow rate) is somewhere between $0.3 \div 0.4 m^3$/hour. These parameters allow the reactor water to be purifyed to the transparency of the distilled water.

The capacity of the filter is only 16 l and it was easily to surround it by a lead shield 130mm thick. The filter was mounted in the pump room of the primary loop. During the operation the filter does not need to be looked after and it is easily regenerated by washing off the particles precipitated on the membranes. The filter release of detonating gas of about 20 l/hour during the operation is its main drawback. But in our case it is not so essential because radiolysis produces about 300l/hour of detonating gas and the primary loop is equipped with a deaeration system for detonating gas removal. The deaerator is installed on the by-pass of the primary loop (Fig7). 10% of all coolant capacity is passing through this system. The deaerator consists of six grid plates with the diameter of 1m. The water is released from the dissolved detonating gas and enters the common flow of the coolant. The air formerly was thrown out into the atmosphere. The exhaust air contains not only detonating gas mixture but also all the radioactive gases dissolved in the primary loop water. A closed loop system of deaeration was designed to reduce fume-off into the atmosphere (10). The air exhausted from the deaerator with 0.5-1% content of detonating gas is heated and passes through the platinum catalysers where the detonating gas is quietly burnt up. Then the air passing through the condenser is cooled and released from water, and then through the compressor the air returns to the deaerator outlet. This system is in

operation since the end of 1962 and decreases the fume-off by 10 times.

II. THE REACTOR EMPLOYMENT.

There are vertical holes in beryllium reflector where experimental channels are put in (Table 4, Fig.1). Two kinds of channels are employed: "dry" channels in which containers with samples are irradiated without any forced cooling and "wet" channels in which the water in the primary loop flows under pressure of 3.5m.w.c. As was previously mentioned there are a water cavity in the core with the "wet" channel and two "wet" channels inserted instead of fuel elements for irradiation in the fluxes of fast neutrons. During the irradiation the temperature of samples changes in a wide range depending on the sample material, its packing and way of cooling. For example, with 28mm dia. specimens placed in an uncooled container with a 2-mm fixed air gap, at 5-MW reactor power, the temperature measured for steel was 510°C, that for aluminium 150°C. Minimum temperatures are in the range of 50-70°C. To calculate the temperatures specific heat release for some materials has been measured at the reactor power of 5 kW. The results of linear calculations for the nominal reactor power are presented in Table 5.

Loading and unloading of irradiated specimens in vertical channels of the reflector are carried out during power operation of the reactor. The minimum time for the transportation of the sample irradiated at 10MW from the irradiation hole to the measuring instrument is 20÷30min.

Horizontal channels are made of tubes with 60mm inner dia. (3 channels) and 100mm inner dia. (6 channels). Their ends are inserted into the holes of the beryllium reflector with the diameter of 88 mm and 128 mm respectively. All the channels have the same structure (Fig.8). There is a distance of 10 meters between the outlet hole and the wall of the experimental hall.

As a rule, measurements are carried out in all the horizontal channels simultaneously except the cases when variable reactor power is required for an individual measurement.

Physical equipment chiefly presents stationary installations with the exception of three horizontal channels in which instruments are arranged only during measuring processes. These channels are particularly used for investigations on fission physics.

One of the main problems of nuclear physics solved on the reactor is a complex study of $n\gamma$-reaction. This implies parallel investigation for certain nuclei(mainly of odd-odd ones as less studied) of γ-rays spectra and their intensities; investigation of conversion electron spectra arising in the reaction and different schemes of coincidences for a prompt radiation. Such investigations permitting to determine not only the energy of gamma-rays and their intensities but also their multipolarities, spins and successions ensure the complete nucleus level diagrams to be drawn. For the investigations of this problem we use simultaneously three radial horizontal channels and recently a special tangent channel was made.

To study the spectrum of energies of γ-quanta and its relative intensities the crystal-defractional γ-spectrometer Cauchois with 4-m distance from the curved crystal to the detector is arranged (Fig.9). High resolution and accuracy of the instrument (12) and also the possibility of remote motion of the source from the region with high neutron flux to the region with low neutron flux for the selection of γ-bands belonging to isotopes and not relating to the prompt γ-rays of reaction permit reliable measurements to be made in this region.

A tangent channel (for attenuating γ-radiation of the core) was used to investigate conversional electrons of $(n\gamma)$-reaction. From the large target arranged in front of the core, electrons of conversion go through the vacuum tube protected from the magnetic field

to a focussing lens. The subsequent analysis of electron energy is carried out by the double magnetic spectrometer of $\pi\sqrt{2}$ type.

Two other radial beams of the reactor supplement these investigations with measurements of γ - γ - coincidences (13) (scintillation spectrometers with the delayed coincidence measurement) and γ - e, and e - e - coincidences with the double toroid spectrometer employment (14) whion permits also to investigate e- γ and e-e angular correlations.

Besides we study short-living and isomeric states of nuclei obtained in the reactor. For these purposes we use rabbit and specimens' delivery systems previously described in I.A.Kondurov and D.A.Iashin's report (15), so we describe only a new pneumatic rabbit system for the magnetic spectrometer which is placed on the reactor radial thimble. The arrangment (16) is to investigate γ-rays spectrum of short-living isotopes formed in the reactor. There are two lines in pneumatic rabbit for specimens spools' movement. In turn one of the specimens is irradiated in a channel (beryllium reflector region) while the other is delivered to the magnetic spectrometer of "Elotron" type arranged in the hall. γ-rays of a specimen knock out electrons from the curved (to intensificate luminous intensity) thin target. The electrons are analyzed by the magnetic field of a special shape (Fig.11).

We use two radial channel to investigate the fission reaction. The main aim of these investigations is to clear up the mechanism of fissionable process, which is related to studying the characteristics and particle correlations formed during the elementary fissionable process. A study was made of energy and angular distribution of neutrons emitted at the fission of U^{235} by the thermal neutrons (17), angular distribution of γ-rays of the fission of U^{235}, U^{233} and Pu^{239}, the relation of kinetic energy with symmetrical fission yield (19) and so on.

As an illustration we can point out, for example, that the study of lifetime of exoited states of thermal-neutron fission fragments by the method of γ-spectrum measurement (18) whion is collected by the narrow collimator moved along the fragment's path showed that the main p[illegible] f γ-rays is emitted for the time less than 5.10^{-11} sec and only 5-10% of radiation correspond to the time interval 3.10^{-10}-2.10^{-8} sec.

As such investigations do not need bulky apparatus (for detecting semiconductor counters are frequently used) echeloned assemblies are used to organize such work that is the reactor beam passes simultaneously two targets in two different instruments arranged one after another. (After that the beam is caught by a beam trap, as in all other horizontal channels, in order to diminish radiative background in the hall).

Three horizontal channels, thermal column and some vertical channels of the reactor are employed to carry on investigations on solid state physics. Characteristic features of such a work with horizontal channels are: preliminary neutron monochromatization, installation of filters for "cold" neutrons in the reactor channels and also the creation of polarized neutron beams with the help of neutron reflecting mirrors.

Similar investigations are being carried on in several directions (20). The excitement of spin waves in ferromagnetics (under different temperatures) for small scattering angles of neutrons is studied on one channel with the help of polarized beam of incident neutrons. The peculiarity of the method is the determination of the polarization degree of neutrons after scattering.

Phonon spectra of semiconducting crystals are investigated on the installation (with cooling Be-filter in a reactor channel), where a time-of-flight selector with a 5-metre flying base for measurements of neutron energies is used. Analogous investigation of phonon spectra of polymeric substances is conducted on two crystal type installation in which monochromatisation of neutrons and analysis of their energies are carried on by reflecting from lead crystals.

With the help of neutron-diffraction camera in one of the horizontal channels of the

reactor the magnetic ordering of ferrites is studied.

The reactor permits to investigate successfully irradiation damage in semiconductors. Energy levels spectra appearing in the forbidden zone of germanium under the influence of fast neutrons at room temperatures as well as at liquid nitrogen temperature were studied (21).

At liquid nitrogen temperature 11 donor and acceptable levels have been discovered for the display of which additional heating was necessary ("defect ripening").

Similar tests are carried on in vertical reactor channels with the use of liquid nitrogen feeding into a special cryostat.

The work on radiochemistry with the use of reactor hot cells is connected with elaboration of methods for preparation of radioactive isotopes with high specific activity necessary for scientific research. As an illustration we can mention a method of P^{32} purification and emission with the specific activity up to 10 curie/mg.

Such preparations are employed for investigations on biology and on β-spectroscopy. Tests on radiation influences on biological objects (animals) can be carried on in three special thimbles placed in the concrete shield of the reactor. A special cage equipped with a ventilation system ensuring normal conditions for the animals and with a system for dosimetrical control can be lowered into a thimble with a big oval size (40x60cm). Fast-neutron flux in cage region is usually 3.10^6 n/cm^{2}sec. By selecting the filters surrounding the cage the ratio of mixed flux components can be varied but not in high proportions.

Mainly such tests are made to determine personnel radiation resistance and to work out radiation protection methods.

All the described installations are situated in the reactor hall. Though it is not dangerous to stay in the hall during reactor's work (as there exist neutron beam traps), all the installations have provisions for remote control from special rooms with control boards for each reactor horizontal channel. Moreover, to improve and speed up measurements, reactor installations are served by a common system of centralized information collection which can simultaneously conduct multichanneled calculations for a number of "subscribers".

Experimental possibilities are limited because of the absence of reactor tangent channels. It is well illustrated by the crystaldiffraction spectrometer. Forced gamma shielding leads to the reduction of neutron flux on the specimen. Though the part of lead screen is placed even in the core instead of beryllium elements (Fig.9) high neutron flux of the reactor is not essentially used. On the specimen the flux reaches only $\sim 2.10^{12}$ n/cm^{2}sec. Besides fast neutron flux does not diminish and accounts considerably for the common background of measurements.

A hollow in biological shielding from the telescoping thermal column was used to form tangent and tangential channels. Two channels were drilled in concrete and the thermal column graphite was replaced by protective disk with channels for beams extraction (Fig.10). Naturally, we failed to bring these channels into the reactor tank up to beryllium reflector but these channels had definite advantages in comparison with radial channels as their background-effect ratio is considerably less (Table 6).

The small diameter of the horizontal channels at the outlet of biological shielding is another drawback of their design. To place some experimental devices except collimators in channels is extremely difficult.

Using again the hollow from the thermal column, additional channels No.12 and No.15 (Fig.10) were formed; they enable the monochromator crystal to be placed nearer to the core. The removable shielding permits easy maintenance of the apparatus arranged at the outlets of these channels and reduces specimen background of monochromator scattering.

CONCLUSION.

The research WWR-M reactor permits carrying on investigations with the use of neutron flux up to 3.10^{14} n/cm^{2}sec. Reactor investigations with horizontal neutron beams and with specimens irradiated by high neutron fluxes are carried on.

The creation of some additional reactor systems (a closed air system, water-supply system etc.) guarantees the safe reactor operation at nominal parameters.

The experience of the reactor operation and investigations showed that the absence of special-purpose channels hinders certain investigations on this reactor. The reactor has a serious drawback: it has only standard radial horizontal channels.

At present it is somehow compensated by the provision of additional tangent and tangential channels.

As to the further improvement of the reactor we hope to reconstruct the vertical experimental channels.

TABLE I.

Operating Conditions of Coolant in WWR-M Reactor.

Mean power density	$\frac{MW}{l}$	0.2
Maximum calculated temperature of fuel element cladding	^oC	90
Mean temperature of water-coolant in the core	^oC	45
Water-coolant bulk velocity in the core	m/sec	6
Specific heat-transfer surface of fuel elements per 1 kg of U^{235}	m^2/kg	7.2

TABLE II.

Quality of Water Used as a Coolant in WWR-M Reactor.

Parameter		Supplying water	Water of the primary circuit
Specific Electric resistance	Ohm.cm	10^6	$(2\div5).10^5$
pH	-	6.8	5.2÷6.2
Dry residue	$\frac{mg}{l}$	1	5÷10

523

Table 3.

Periodicity of Quality Water Control in WWR-M Reactor.

Parameter	Periodicity of Control
Specific electric-resistance	Constantly
pH	Weekly
Corrosive elements: iron, aluminium, beryllium	Monthly
Admixture: chlorine, silicon, nitrogen compounds, organic compounds	Monthly
Activity of dry residue	Weekly
Activity of fission isotopes: iodine, strontium, barium etc.	Weekly
Transparency of water	Weekly

Table 4.

Vertical Experimental Channels of WWR-M Reactor.

	Unit of measure	Channel in the reflector				Channels in the core	
Diameter of reflector hole	mm	48	70	90	110	Core channels	Water channel
Inner diameter of channel	mm	41	60	-	-	30	41
Quantity of channels	pc	9	1	2	1	2	1
Thermal neutron flux	$10^{14} \times \frac{n}{cm^2 sec}$	1.4+0.3	0.5+0.3	0.5+0.3	0.9+0.4	1	3+1

Table 5.

Heat Release in the Specimens Irradiated in 40mm "Dry" Experimental Channel at 10-MW Reactor Power.

Material	Heat-Release, W/g
Copper	0.5
IX18H9T Steel	0.3
Aluminium	0.4
Beryllium	1.2
Water	1.2+2.0

325

Table 6.

Characteristics of New Channels and One Radial Channel of WWR-M Reactor of the Physical-Technical Institute.

Channel	ϕ_{th} Maximum thermal neutron flux in the channel	ϕ_{th} Maximum neutron flux at the outlet channel	ϕ_f Fast neutron flux at the outlet channel	D_γ γ-rays power at the channel outlet	$\phi_{th} : \phi_f : D_\gamma$ Flux relation at the channel outlet
	$\frac{n}{cm^2 sec}$	$\frac{n}{cm^2 sec}$	$\frac{n}{cm^2 sec}$	$\frac{r}{sec}$	$\frac{n}{cm^2 sec} : \frac{n}{cm^2 sec} : \frac{r}{sec}$
No. 1 Radial	$0.5.10^{14}$	3.10^9	3.10^8	6.10^7	1:0.1:0.02
No. 10 Tangent	6.10^{11}	8.10^7	8.10^5	6.10^4	1:0.001:0.001
No. 11 Tangential	2.10^{12}	5.10^8	$2.4.10^7$	8.10^5	1:0.046:0.0016
No. 16 Tangential	2.10^{12}	5.10^8	$1.8.10^7$	6.10^5	1:0.04:0.0012

LIST OF REFERENCES.

1. D.M.Kaminker - "Vestnik Aokademii Nauk of the USSR" 1961, No.10, p.60-64.
2. D.M.Kaminker - "Vestnik Aokademii Nauk of the USSR" (to be published).
3. V.V.Gonoharov, L.I.Rusinov, U.G.Nickolaev, V.A.Shustov and G.V.Skorniakov - II Geneva Conference, 1958, paper, p.2185.
4. D.M.Kaminker, K.A.Konoplev, U.V.Petrov, R.G.Pikulik - IAEA Symposium on Expotential and Critical Experiments, 1963, report Sm-42/84.
5. K.A.Konoplev, R.G.Pikulik, L.I.Rusinov, V.A.Soloviov, V.A.Shustov - Rev.Phys. Acad. RPR, 1961, 6, Suppl., 323-386.
6. U.V.Petrov, T.I.Sumbayev - IAEA Symposium on Physics Problems and Materials for Control Rods of Reactors, 1963, paper Sm-46/25.
7. V.D.Ganja, K.A.Konoplev, V.D.Trenin, V.T.Sharov - "Atomnaya Energiya"(to be published),
8. Hatcher and Rae - "Nuol.Sci.Eng." 1961, 10, 1504.
9. V.D.Ganja, K.A.Konoplev, R.N.Rodionova, V.P.Sajkov, V.D.Trenin, V.T.Sharov - "Rev.Phys. Acad. RPR", 1961, 6, Suppl., 629-633.
10. M.V.Pasechnic, I.P.Barchuc, D.T.Pilipets, F.A.Grinevich, M.N.Nasarchuc, S.O.Slesarevski - Conference on Physics and Nuclear Reactor Technique, Prague, 1963.
11. K.A.Konoplev. Rev.Phys. Acad. RPR, 1961, 6, Suppl., 255-261.
12. O.I.Sumbayev, A.I.Smirnov - "Nuol.Instr.Methods" 1963, 22, 125-137.
13. A.M.Brestovoi, D.M.Kaminker, I.A.Kondurov - "Jurnal Experimentalnoi i Teoreticheskoi Physicy" 1963, 45, 892.
14. A.V.Borovikov, V.Gvozdev, G.D.Porsev - "Pribori i Technika Experimenta", 1961, No.4, 33-34.
15. I.A.Kondurov, D.A.Yashin - "Production and Use of Short-lived Radioisotope from Reactors" vol.1, Vienna 1963, p.83-92.
16. A.G.Sergeev, N.A.Voinova, B.S.Dgelepov, U.V.Caliniohev, D.M.Kaminker - "Program and Theses of XIV Annual Conference on Nuclear Spectroscopy", 1964.
17. M.V.Blinov, N.M.Kasarinov, A.N.Protopopov - "Jurnal Experimentalnoi Teoreticheskoi Physicy", 1962, 142, No.4, 1017.
18. G.A.Petrov, D.M.Kaminker, G.V.Valskii, L.A.Poneko - "Jurnal Experimentalnoi Teoreticheskoi Physicy" (to be published).
19. S.S.Kovalenko, K.A.Petrociak, V.N.Adamov - "Atomnaya Energiya", 1962, 13,No.5, 474.
20. G.M.Drabkin, D.M.Kaminker - Conference on Physics and Nuclear Reactor Technique, Prague, 1963.
21. R.F.Konopleva, S.R.Novikov, S.M.Rivkin - "Physica Tverdogo Tela", 1963 5, 1842.

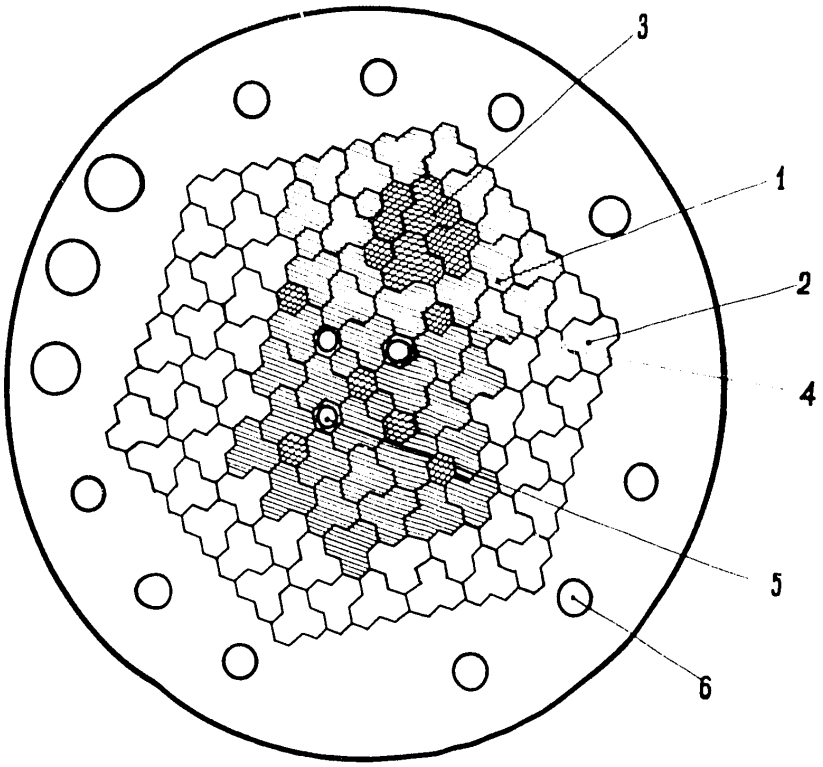

Fig.1. Diagram of the First Reactor Loading.
1.Fuel elements. 2.Beryllium elements. 3.Water cavity. 4.Shim and control rods. 5.Safety rods. 6.Vertical experimental channels.

325

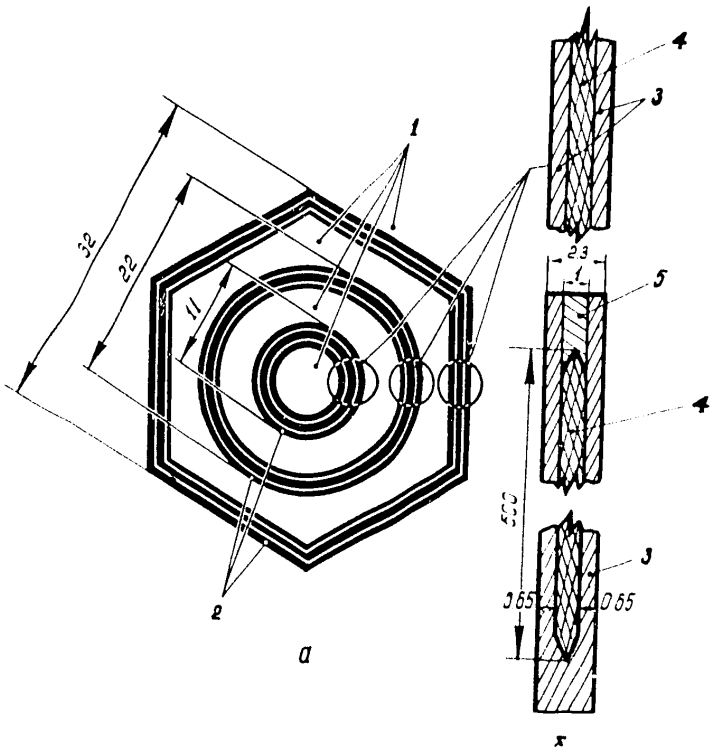

Fig.2.Section of a Fuel WWR-M Element.
a)Cross-section.b) Longitudinal-section.
1.Gaps for Cooling Water.
2.Fuel element tubes.
3.Aluminium fuel element can. 4. Nuclear fuel layer.
5. The ring diffusive-welded with fuel element can with nuclear fuel layer.

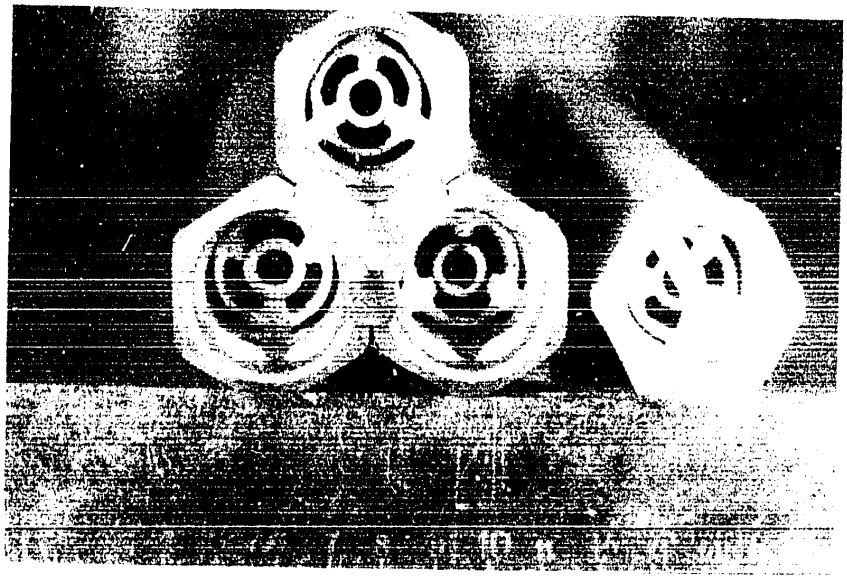

Fig.3 Photograph of Fuel Elements. Top View.

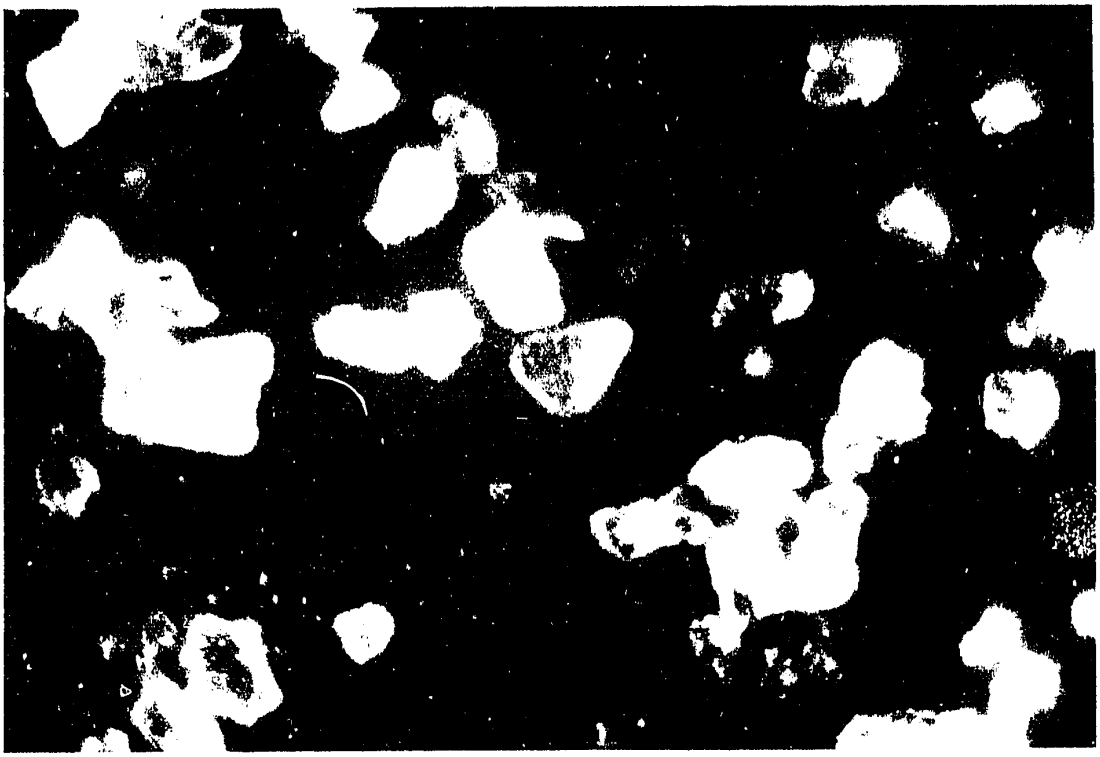

Fig.4. Photograph of Particles Suspended in the Water of the primary Reactor Circuit. Magnified 800 times.

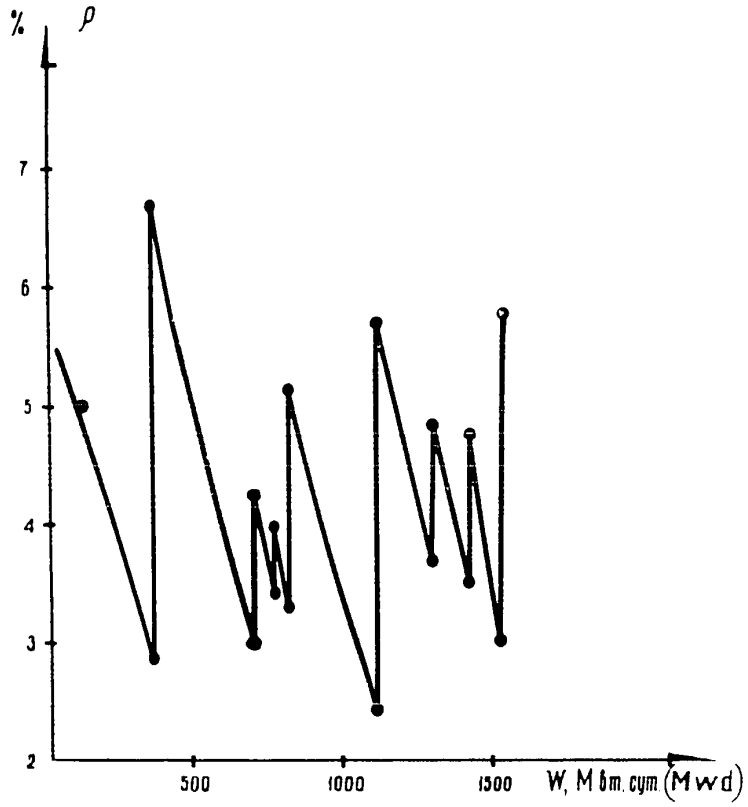

Fig.5 Diagram of Reactivity Changes Against Fuel Burning in WWR-M Reactor.(The Breaks of the Line Correspond to Additional Charges and Overloadings of Fuel Elements).

325

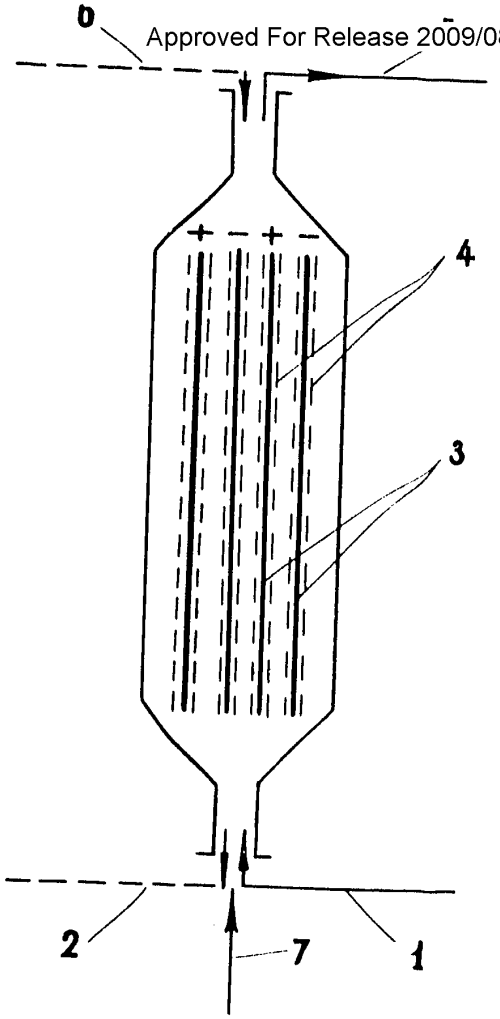

Fig.6. Scheme of Electrophoretic Filter Purifying Reactor Water.
1. Inlet for water suspension. 2.Removing of the pulp. 3. Electrodes. 4.Membranes. 5.Outlet for purified water and detonating gas bubbles. 6.Water feeding to remove the pulp. 7. Compressed air feeding for membrane purification

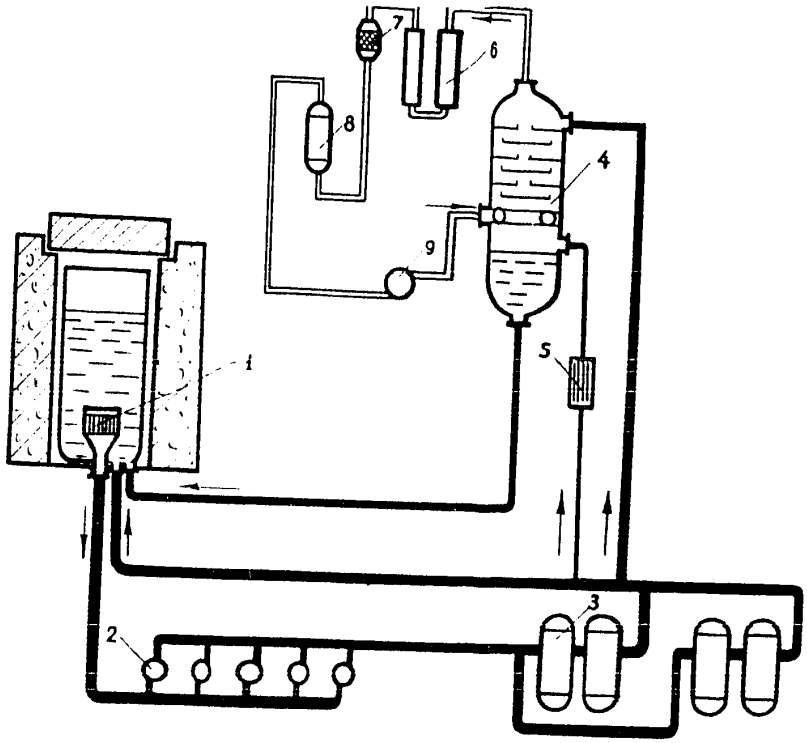

Fig.7. Scheme of Inclusion of Electrophoretic Filter and Closed Deaerator System in the Primary WWR-M Reactor Circuit.
1.Core.2.Circulating pumps of the primary circuit. 4.Deaerator. 5. Electrophoretic filter.6.Air heater.7.Catalytic burning of detonating gas. 8.Condenser. 9.Compressor.

325

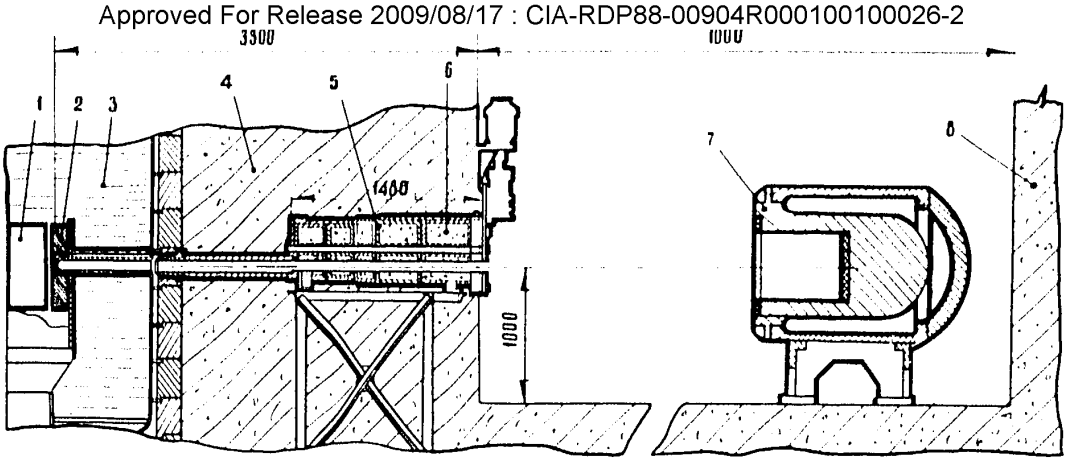

Fig.8. Vertical Section of Horizontal WWR-M Reactor Channel.
1.The core. 2.Beryllium reflector. 3.Water. 4.Concrete. 5.Gate. 6.Concrete filling. 7.Neutron beam trap. 8.The wall of the experimental hall.

All the dimensions are given in millimetres.

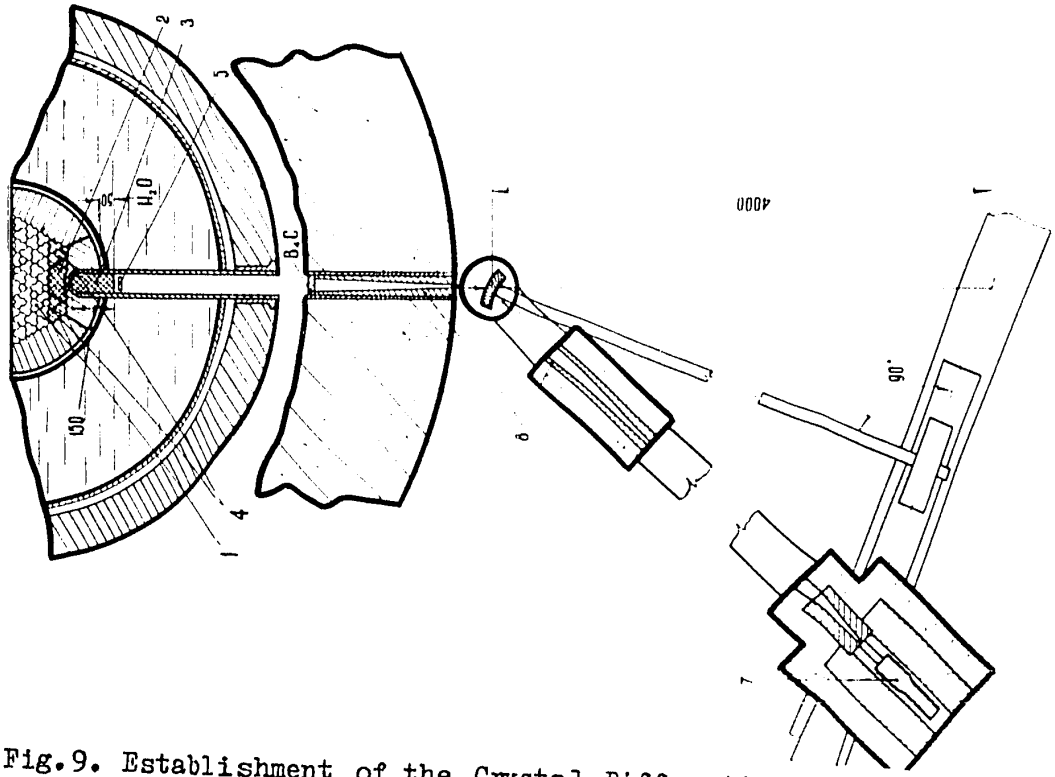

Fig.9. Establishment of the Crystal-Diffraction Spectrometer in Channel No.2 of WWR-M Reactor.
1.The core. 2.Cooled lead shield placed instead of a part of beryllium elements. 3.Intrachannel lead shield. 4.Beryllium elements. 5.Specimen. 6.Curved crystal. 7.Detector. 8. Collimators.

The dimensions are given in millimetres.

325

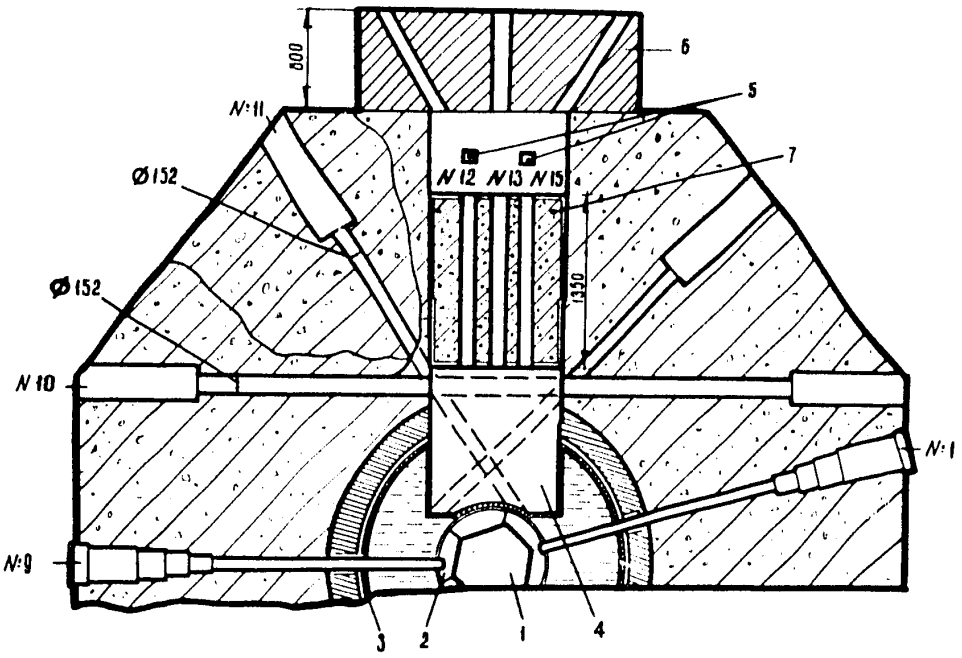

Fig.10. Arrangement of New Experimental Channels in WWR-M Reactor.

1.The core. 2.Beryllium reflector. 3.Reactor tank. 4.Hollow for the telescoping thermal column. 5.Arrangement of crystal-monochromator. 6.Mobile cast iron shielding. 7.Concrete plug. No.1 and No.9 - Radial channels placed 1000mm above the hall floor. No.10 - Tangent channel placed 1250mm above the floor. No.11 - Tangential channel placed at a height of 750mm. No.16 - Tangential channel placed at a height of 1250mm. No.12 and No.15 - Channels for crystal spectrometers placed 1000mm above the floor.

All the sizes are given in millimetres.

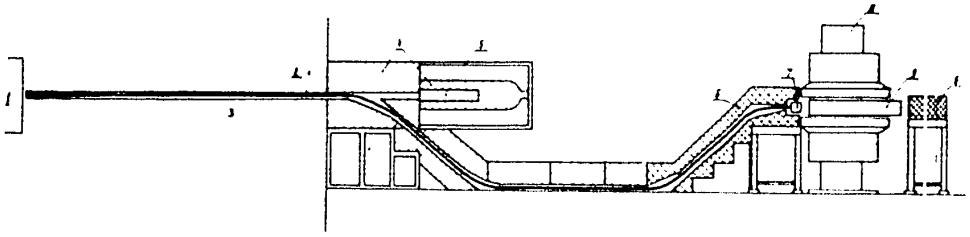

Fig.11. Pneumatic Rabbit System for Apparatus of "Elotron". 1.Reactor core. 2.Tubes for pneumatic rabbit system. 3.Concrete reactor shield. 4.Outer shield. 5.Paraffin with boron carbide. 6.Lead shield. 7.Detector of pneumatic rabbit system. 8.Electromagnet of spectrometer. 9.Vacuum chamber.

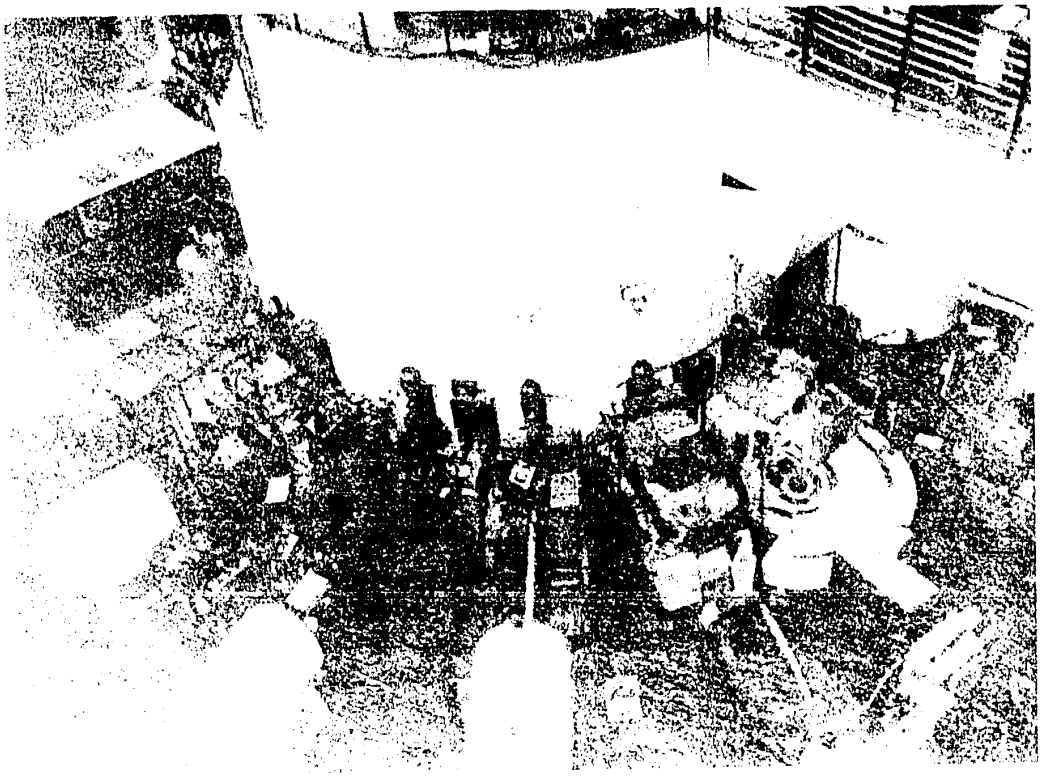

Fig.12. Photograph of the Experimental Hall of the Reactor.

325